

REC'D 23 JUL 2004

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11 030832
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03102013.4 ✓

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Anmeldung Nr:

Application no.: 03102013.4 ✓

Demande no:

Anmeldetag:

Date of filing: 04.07.03 ✓

Date de dépôt:

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Optical diffraction element

In Anspruch genommene Priorität(en) / Priority(ies) claimed /Priorité(s)
revendiquée(s)

Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

G02B6/34

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of
filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LU MC NL
PT RO SE SI SK TR LI

Optical diffraction element

The invention relates to an optical diffraction element comprising a diffraction layer, which is divided into diffraction strips, which alternate with intermediate strips.

The invention also relates to a method of manufacturing such a diffraction element, to an optical record carrier reading device provided with such an element and to an
5 optical record carrier provided with such an element.

A well-known diffraction element is an optical diffraction grating, wherein the diffraction strips are the grating strips. Diffraction gratings are widely used in the optical
10 field, either as stand-alone elements or integrated with other optical components. A diffraction grating splits an incident beam into a, non-deflected, zero order sub-beam, a pair of deflected first order sub-beams and pairs of sub-beams, which are deflected in higher diffraction orders. There are two main types diffraction gratings: amplitude gratings and phase gratings, which both may be reflective or transmissive. An amplitude grating
15 comprises grating strips which absorb incident radiation, whilst the intermediate strips transmit or reflect incident radiation. A phase grating introduces a phase, or optical path length, difference between beam portions incident on grating strips and beam portions incident on intermediate strips, because the grating strips have another refraction coefficient or are situated at another level than the intermediate strips.

20 In view of new applications, for example in miniaturised optical devices or in the optical recording technology, there is steadily demand for diffraction gratings having an ever decreasing grating period. Grating period, or grating pitch, is understood to mean the sum of the width of a grating strip and the width of an intermediate strip. The manufacture of gratings with small pitches, in the micron range, by conventional techniques, such as by
25 means of electron beam writing and lithographic techniques, is very expensive so that such grating are costly elements.

It is an object of the invention to provide a new type of diffraction element such as a grating, which element shows a high contrast, can be manufactured in an easy and cheap way and thus is a cheap component. This diffraction element is characterized in that the diffraction strips comprise nano-elements tubes, which are embedded in the diffraction layer and all have their symmetry axis substantially aligned in one direction.

Substantially aligned in one direction is understood to mean that in principle the symmetry axis of all elements have the same, said one-, direction, but that small deviations of this one direction are possible without affecting the grating behaviour. In case of a linear diffraction grating the said direction is parallel to or perpendicular to the direction of the grating strips. The diffraction element may also be a two-dimensional grating having a first set of grating strips extending in a first (X-) direction and a second set of grating strips extending in a second (Y-) direction perpendicular to the first direction. The grating strips of a linear or two-dimensional grating may also extend in (a) direction(s) diagonal to the X- and Y-direction. The diffraction strips may also annular strips and the diffraction element comprising such strips may constitute a diffraction lens, for example a Fresnel zone lens.

Nano-element is a general term for nanotubes and nanowires, which are also called whiskers, and small prisms. Nano elements are very small bodies having a more or less hollow (nanotubes) or filled (nanowires) cylindrical or prismatic shape having a smallest dimension, for example a diameter, in the nano meter range. These bodies have a symmetry axis, the orientation of which determines electrical and optical properties, such as the absorption characteristics of the material wherein they are embedded. When reference is made hereinafter to their orientation, this relates to the orientation of their central cylinder axis or prism axis.

Nano-elements have been described for a variety of materials, such as:

- indium phosphide (InP) (X Duan et al., Nature 409 (2001), 66; J. Wang et al., Science 293 (2001), 11455-1457;
- zinc oxyde (ZnO) (M. Huang et al, Science 292 (2001), 1897-1899;
- gallium arsenide (GaAs) and gallium phosphide (GaP) (K. Haraguchi et al., Appl. Phys., Lett. 60 (1992), 745; X. Duan et al., Nature 409 (201), 66;
- silicon carbide (SiC) (S. Motojima et l, J. Crystal Growth 158 (1996), 78-83;
- silicon (Si) (B. Li et al., Physical Review B 59, 3 (1999) 1645);
- boron nitride (BN) (W. Han et al., Applied Physics Letters 73, 21 (1998) 3085);
- nickel dichloride (NiCl₂) (Y. Rosenfeld Haconen et al., Nature 395 (1998) 336;

- molybdenum disulphide (MoS_2) (M. Remskar et al., Surface reviews and letters, vol. 5 no. 1 (1998) 423;
- tungsten disulphide (WS_2) (R. Tenne et al., Nature 360 (1992) 444, and
- carbon (C) (Iijima, S., Nature 354 (1991), 56-58, Ebbesen T.W. and Ajayan P.M. Nature 358 (1992), 220).

Particularly carbon nanotubes have been well studied. They are one-layer or multi-layer cylindrical carbon structures of basically graphitic (sp^2 -) configured carbon. The existence of both metallic and semiconducting nanotubes has been confirmed experimentally. Furthermore, it has recently been found that single-walled carbon nanotubes having a thickness of, for example 4-Angstrom aligned in channels of an AlPO_4 -5 single crystal exhibit optical anisotropy. Carbon nanotubes are nearly transparent for radiation having a wavelength in the range of 1,5 μm down to 200 nm and having a polarisation direction perpendicular to the tube axis. They show strong absorption for radiation having a wavelength in the range of 600 nm down to at least 200 nm and having a polarisation direction parallel to the tube axis (Li Z.M. et al., Phys. Rev. Lett. 87 (2001), 1277401-1- 127401-4).

Similar properties have been found for nanotubes (or nanowires) other than those consisting of carbon. Nanotubes therefore most conveniently combine the following features. They absorb radiation in a broad range of wavelengths depending on the orientation of the nanotubes relative to the polarisation direction of said radiation, and the orientation of the nanotubes can be directed and/or stabilised mechanically and/or by an electric field.

A configuration of linear strips, which comprise nano-elements all having their symmetry axis aligned, i.e. in the same direction, which strips alternate with intermediate strips, thus acts as an amplitude grating for linearly polarised radiation having its polarisation direction parallel to the alignment direction, because the intermediate strips are transparent for this radiation.

In the paper "Spinning continuous carbon nanotube yarns" in Nature, Vol. 419, 24-1-2002, page 801, which paper describes how carbon nanotubes can be self-assembled into yarns of up to 30 cm in length simply by being drawn out from superaligned arrays of such tubes, it is remarked that a CNT polariser can be constructed by parallel arrangement such CNT yarns. This paper thus discloses the polarising properties of a specific structure of carbon nanotubes, but does not disclose a diffraction grating having grating strips formed out of such nanotubes.

A grating comprising carbon nanotubes is described in the paper: "Surface sustained permanent gratings in nematic liquid crystals doped with carbon nanotubes" in

Optics Express vol.10, no.11, 2002, pages 482-487. However this grating is a refractive index grating, or phase grating. It comprises a layer of nematic liquid crystal, which is doped with multiwalled carbon nanotubes. A grating is formed in this layer in a holographic way, i.e. by means of two interfering beams. These beams cause a periodical redistribution of the doping material at the interface between the LC layer and an aligning layer. The radiation absorbing nanotubes act as traps of radiation induced surface charges, cause the radiation-induced modulation of the easy axis in the LC bulk and sustain the permanent grating through the continuum effect of the liquid crystal material. It is remarked in the paper that there may a polarisation dependency, but this is coupled to the re-orientation of the LC and not contributed to the carbon nanotubes. This grating is principally a LC grating, wherein the nanotubes are auxiliary means, and thus of a different type than the grating according to the invention, wherein the aligned nano-element tubes only provide the grating function.

Nano-element tubes are very small in one dimension; for example, carbon nanotubes may have a width of 0,3 nm till approximately 100 nm. These elements therefor can be packed to a great density and their size is not a main limiting factor for the width of the grating strips and thus the pitch of the diffraction grating.

As the different types of nano-element tubes show similar absorbing properties, the diffraction element according to the invention may comprise different types of nano-element tubes on the understanding that one diffraction element comprises one type of nano-element tubes.

A first embodiment of the diffraction element is characterized in that the nano-element tubes are nanowires.

A second and preferred embodiment of the diffraction element is characterized in that the nano-element tubes are nanotubes.

Nanotubes, and especially carbon nanotubes, provide a very large contrast between radiation, which is polarised perpendicular and parallel, respectively to the tube direction, i.e. the axis of anisotropy. For example, for incident radiation having a wavelength of 405 nm an absorption contrast (expressed in terms of optical density: OD) of 4-8 OD can be obtained. Furthermore, already with small concentrations of nanotubes in a transparent layer a useful diffraction element can be obtained.

In addition, nanotubes per se are cheap, lightweight and easy to manufacture and to recycle. By including nanotubes in a transparent medium to obtain a diffraction element, these advantages are transferred to this medium and to the diffraction element.

Nanotubes are also very stable and do not readily decay or racemize under every day conditions of diffraction elements. Thus, a pattern of nanotubes once produced is also very stable and does not decay readily.

A further preferred embodiment of the diffraction element is characterized in
5 that the nanotubes are carbon nanotubes, especially single wall carbon nanotubes.

Single wall nanotubes, especially single wall carbon nanotubes exhibit a particularly pronounced anisotropy, enhancing the advantages inherent in the diffraction element of the invention.

The diffraction element may be a transmission element or a reflective element.
10 For a transmission element besides the diffraction layer also the substrate carrying the diffraction layer is transparent. A reflective diffraction element can be obtained by covering the transparent diffraction layer with a reflective layer, i.e. by arranging a reflective layer between the diffraction layer and the substrate, which may be transparent or not. The substrate may also be formed by another optical element of an optical device of which the
15 diffraction element forms part.

A particularly preferred embodiment of the diffraction element is characterized in that, the diffraction layer is essentially solid at temperatures below 30° C.

Such a diffraction element shows an enhanced stability of the orientation of the nano-elements. These elements are thus in effect frozen and prevented from accidentally
20 changing their orientation. To obtain said solidity a transparent material that is essentially solid at temperatures below 30° C may be used for the diffraction layer. The solidity can also be achieved by placing the nanotubes on top of a solid surface and affixing the nanotubes to the solid surface by means of van der Waals forces or glue. Within the scope of this invention, a diffraction layer is considered to be essentially solid if the viscosity of the layer at and below
25 30° C is at least 10 PA s (100 Poise), more preferably higher than 20 PS s, even more preferably higher than 50 PA s (500 Poise). At viscosity's lower than 10 PA s the grating layer can be considered as being essentially liquefied. Preferably the diffraction layer is essentially solid up to temperatures of 80° C more preferably up to temperatures of 100° C. This enhances the stability of the orientation of the nanotubes during normal conditions of
30 use of a diffraction element.

Preferably the diffraction element is characterized in that the material of the diffraction layer is liquefiable at temperatures below the temperature at which the nano-element tubes get destroyed.

The diffraction layer can then be liquefied by decreasing the viscosity of the layer if this layer is solid otherwise. It is therefore not necessary to liquefy or otherwise change the structural integrity of the nanotubes in the diffraction layer. Generally, nanotubes can withstand temperatures of 100° C; carbon nanotubes, for example are destroyed at 800-
5 1000° C. Liquefaction allows to reorient the nanotubes of a liquefied diffraction layer.

The diffraction element may be further characterized in that the material of the diffraction layer is selected from the group consisting of glasses with melting or glass temperature below 800° C, acrylic thermoplastics and paraffin's.

Such transparent materials facilitate to realise diffraction layers, which are
10 essentially solid at temperatures below 30° C. They also allow realising diffraction layers, which are liquefiable at temperatures where the nanotubes (especially carbon nanotubes) are not substantially destroyed and which can be re-solidified after such liquefaction.

The main application of the invention is the use of the diffraction structure in a linear or two-dimensional grating wherein the advantages of the invention are used optimum.

15 The invention can also be used in other diffraction elements, such as a Fresnel lens.

The invention also relates to methods of manufacturing the diffraction element described herein above.

A first method is characterized by the steps of

- printing a pattern of strips comprising a solution containing nano-element tubes;
- 20 — aligning the nano-element tubes in a required direction by means of an electrical or magnetic aligning field, and
- fixing the orientation of the nano-element tubes in said direction by treating the solution in the presence of the aligning field.

The treating may consist of evaporating the solution so that the nano-elements
25 remain as isolated elements, or of polymerising solution, i.e. solidifying this solution. The aligning field may be a magnetic field or an AC or DC electrical field; preferably it is an AC electrical field.

The paper "Orientation and purification of carbon nanotubes using ac electrophoresis" in J. Phys. D; Appl. Phys. 31 (1998) L34-L36 describes how nanotubes can
30 be oriented by means of electrophoresis. If an AC electrical field is applied, nanotubes will move to the electrodes and are oriented, whereby the degree of orientation increases with increasing frequency of the electrical field. The paper does not disclose a diffraction grating based on nanotubes. For the manufacture of such a grating it is important that the electrical field remains present during fixation of the orientation of the nanotubes.

A second method of manufacturing the diffraction element is characterized by the steps of:

- spin-coating a surface area of a substrate with a thin film of a solution containing nano-element tubes;
- 5 – aligning the nano-element tubes in a required direction by means of an electrical or magnetic aligning field;
- fixing the orientation of the nano-element tubes in said direction by treating the solution in the presence of the aligning field, and
- burning out strip shaped areas of the film thereby obtaining a pattern of strips comprising
- 10 aligned nano-element tubes, which strips form the diffraction strips.

Burning out may be performed by illuminating the solution with radiation of sufficient energy via a mask having a pattern of transparent and non-transparent strips corresponding to the grating pattern. Burning out may also be performed by scanning a sufficient intense radiation beam strip-wise across the solution. In both cases a pattern of

15 strips comprising aligned nano-elements remains, which strips form the diffraction strips. The radiation used for burning out should having an energy, which allows removing strips of the film in a reactive environment. For carbon nano tubes this environment is, for example an oxygen containing environment. It should be prevented that after burning out the strips show a height difference of $\lambda/4$ with the intermediate strips, because a polarisation-insensitive

20 phase grating would be obtained then. If necessary the intermediate strips can be filled with film material that does not comprise nano-element tubes to avoid formation of a phase grating.

A third method of manufacturing the diffraction element is characterized by the steps of:

- 25 – coating a substrate area with a layer of self-assembled material;
- strip-wise modifying the material of the layer so that a pattern of strips, which wet to the substrate surface is obtained and removing the rest of the layer material;
- spin-coating a liquid containing nano-element tubes over the pattern thus obtained, whereby the liquid wets only the bare substrate so that a pattern of liquid strips containing
- 30 nano-elements tubes is obtained;
- aligning the nano-elements tubes in the liquid strips in a required direction by means of an electrical or magnetic aligning field, and

- fixing the orientation of the nano-element tubes in said direction by treating the liquid in the presence of the aligning field, thereby obtaining a pattern of strips containing aligned nano-element tubes, which form the diffraction strips.

Strip-wise modifying of the material of the layer can be performed by scanning the layer strip-wise by, for example, an electron beam or by illuminating the layer with, for example, UV radiation via a mask having a pattern of transparent slits corresponding to the grating pattern of slits. The E beam or radiation destroys the molecules or functional groups of the layer material, which results in a modified wetting behaviour of the material in the illuminated strips. It is also possible to use a micro contact printing process. The advantage of such a process is that it may change the local orientation. The grating strips and intermediate strips need not to be of the same material, but may consist of different materials like silicone nitride and PMMA (polymethyl methacrylate).

A fourth method of manufacturing the diffraction element is characterized by catalytic growing nano-elements on a substrate surface from a layer, which has been deposited on the substrate and comprises nano-element material and burning out strip shaped areas of the layer, thereby obtaining a pattern of strips comprising aligned nano-elements, which strips form the diffraction strips.

Burning out of strips may be performed in the same way as described for the second method. The layer may be a thin metal layer, which may be deposited on the substrate by means of chemical vapour deposition (CVD) or vapour liquid solidification (VLS). Upon heating, this layer is broken up into small spheres, which are quasi-liquid. The lower sides of the spheres crystallise on the substrate and adhere thereto under the influence of catalysing elements present in the layer, for example Fe particles in case of carbon nanotubes.

In general, the above-described processes for producing a layer of nano-elements are known per se, as well as other methods, which may be used. However, the above-described methods of producing a diffraction grating or a diffraction element in general are new.

In a number of applications or optical devices the diffraction grating according to the invention can replace a conventional diffraction grating, such as a grating manufactured by a lithographic technique, by a replication technique or by means of interfering beams (holographically). The new diffraction grating can be used, for example for beam splitting, for beam deflection etc. As the diffraction grating is polarisation sensitive it is very suitable for use in situations where it should be effective for a first beam and non-effective for a second beam. These beams should have mutual perpendicular polarisation

directions, one of which corresponds to the direction of alignment of the nano-elements. Such a situation occurs in a device for recording and reading optical record carriers, which device is a compatible device, i.e. it allows recording and reading optical discs of different formats, such as CD, DVD and Blue Ray discs.

5 An advantageous and inventive application of the diffraction grating is also in the field of optical recording, namely for increasing the density of the information structure, or decreasing the size of the information details, which information can be read out satisfactorily by a read device. Co-pending EP application 03100817.0 discloses that a device, which is designed for reading a record carrier having a given (conventional)
10 information density, can be used for reading a record carrier having a substantially higher (super) information density, if the information layer of the latter record carrier is provided with a diffraction grating. As will be explained hereinafter, if the diffraction grating is a grating according to the invention, the same device allows reading of information having a conventional density and information having the super density. In this way the invention
15 solves also the information density problem in the optical recording technique so that a record carrier, which is provided with a diffraction grating as described herein before also forms part of the invention.

 The invention also relates to a device for reading and recording an optical information carrier of a first type having a first information density and an optical
20 information carrier of a second type having a second information density, which device comprises a radiation source unit supplying a first radiation beam having a first wavelength for co-operating with the first type information carrier and a second radiation beam having a second wavelength for co-operating with the second type of record carrier, and an objective system for focusing the first and second beam on an information layer of the first and second
25 type record carrier, respectively. This device is characterized in that a diffraction grating as described herein above is arranged between the radiation source unit and the objective system in the common radiation path of the first and second radiation beam and in that one of the radiation beams has a first polarisation direction parallel to the direction of the nano-elements in the grating, whilst the other beam has a polarisation direction perpendicular to the first
30 polarisation direction.

 In this device use is made of the property of the novel diffraction grating that is acts as a grating only for a linearly polarised radiation beam having its polarisation direction parallel to the orientation of the nano-elements in diffraction grating and is non-

existing for a radiation beam having a perpendicular polarisation direction. By means of the diffraction grating the two beams can be optimised for the associated type of record carrier.

5 These and other aspects of the invention will be apparent from and elucidated by way of non-limitative example with reference to the embodiments of a diffraction grating described hereinafter and illustrated in the accompanying drawings. In the drawings:

 Figs.1a and 1b show a top view and a cross-section, respectively of a portion of a first embodiment of the diffraction grating according to the invention;

10 Figs.2a and 2b show such views of a second embodiment of such a diffraction grating;

 Figs.3a-3c show different steps of a first method of manufacturing such a diffraction grating;

 Fig. 4a shows the mask used in the first of these steps;

15 Figs. 4b and 4c shows the result of the second and third step in a top view;

 Figs. 5a-5c show different steps of a second method of manufacturing such a diffraction grating;

 Figs. 6a-6c show different steps of a third method of manufacturing such a diffraction grating;

20 Fig.7 shows an embodiment of a device for reading two types of optical record carriers wherein a diffraction grating according to the invention is used;

 Fig.8 shows the modulation transfer function as a function of a normalized spatial frequency in a conventional information layer and in an information layer provided with a grating having aligned nano-elements respectively;

25 Fig.9 shows an embodiment of a read device by means of which this record carrier can be read;

 Fig.10 shows the effect a grating with aligned nano-elements has on the sub-beams diffracted by an information structure, and

30 Fig.11 shows an embodiment of a Fresnel lens provided with a diffraction structure according to the invention..

 As shown in Figs. 1a and 1b the diffraction grating comprises a substrate 2 and a diffraction layer 4. The diffraction layer is divided in a number of grating strips 6, which

alternate with intermediate strips 8. The grating strips comprise a large number of very small nano-elements tubes 10, such as cylindrically or prismatic shaped filled nanowires or, preferably hollow nanotubes and more preferably carbon nanotubes. These elements have an axis of symmetry the orientation of which determines the optical properties, i.e. the absorption of the material wherein they are embedded. The carbon nanotubes have a diameter of the order of 10 Angstrom and a length of the order of 10 μm . In the embodiment of Figs. 1a and 1b the nanotubes have their symmetry axis oriented in the X-direction, i.e. they are aligned in the X-direction. As a consequence the grating strips will absorb a beam b of linearly polarised radiation, which has its polarisation direction, i.e. the direction of the E-vector of the electromagnetic radiation, in the X-direction. The beam portions, which are incident on the intermediate strips 8 where no nanotubes are present, will pass the grating layer 4 and the substrate if the latter is transparent. The configuration of the strips comprising nanotubes and the intermediate strips, which are not provided with nanotubes, thus acts as an amplitude grating for radiation, which is linearly polarised in the X-direction. The grating strips will not absorb radiation, which is polarised in the Y-direction so that for such radiation the grating structure is "invisible" and element 1 forms a transparent plate.

Figs. 2a and 2b shows an embodiment of a diffraction grating 11 wherein the grating strips 16 are provided with nanotubes which are aligned in the Y-direction. These strips will absorb radiation that is linearly polarised in the Y-direction so that this grating acts as an amplitude grating for this type of radiation. For radiation that is linearly polarised in the X-direction element 11 forms a transparent plate.

Figs 1a, 1b and Figs 2a, 2b show only a small number of grating strips and intermediate strips. In reality this number is much larger. The pitch, or spatial period, P of the grating is for example of the order of 1 micron or smaller, but larger than 200 nm in case the nano-elements are carbon nanotubes. The diffraction grating of Figs. 1a, 1b or of Figs 2a, 2b may be a stand-alone element and the diffraction layer is carried then by a proper substrate. The diffraction grating may also be integrated with another element of the optical device wherein the diffraction grating should be included. This has the advantage that the optical device may be more compact, requires less alignment and false reflection at a separate substrate is avoided.

The diffraction grating may also be a reflective grating instead of a transmission grating. In that case the substrate is reflective or a reflective layer is inserted between the diffraction layer and the substrate. The radiation incident on a diffraction grating passes twice the diffraction layer, which means that radiation portions incident on the grating

strips are absorbed twice, so that the contrast between the grating strips and the intermediate strips is increased.

There are several methods of manufacturing the novel diffraction element, which will be described hereinafter at the hand of a diffraction grating.

5 According to a first method a pattern of strips is printed on a substrate by means of a contact printing technique. This method is schematically illustrated in Figs 3a-3c and in Figs 4a-4c. As shown in Fig.3a, a grid 30, which comprises a plate 32 with slits 34, is placed on a substrate 2. Fig. 4a shows a top view of the grid 30. A solution containing nano-
10 elements, for example nanotubes is sprayed over the grid so that the solution reaches the substrate via the slits. As a result, strips of solution 36, at the position of the slits 34 are formed on the substrate, as shown in Fig.3b. A top view of the strips of solution is shown in Fig.4b. The nano-elements 38 in the solution strips 36 show a random distribution of their
15 orientation. In the next step an AC electrical aligning field is applied across the solution pattern, which is illustrated in Fig.3c by means of electrodes 40 and 42. By an electrophoresis process as described in the paper: "Orientation and purification of carbon nanotubes using ac
20 electrophoresis" in J. Phys D: Appl. Phys. 31 (1998), L34-L36, the nano-elements are aligned, i.e. they are all oriented in the same direction, which is the direction of the electrical field. The solution pattern with aligned nano-elements is shown in Fig. 4c. Instead of an AC field also a DC electrical field may be used. It also possible to align the nano-elements by
25 means of a magnetic field.

 As a last step the orientation of the nano-elements is fixed, or "frozen". This can be realised in different ways, depending on the type of solution. For example, the solution can be evaporated so that only nano-elements, which stuck to the substrate by Van der Waals forces, remain. In case the solution is a liquid polymer, the nano-elements can be
30 frozen by polymerisation of the solution. The electrical field is maintained until all nano-elements have been aligned and the manufacture is finished

 Figs.5a-5c show a second method of manufacturing the diffraction grating. In a first step a substrate area having the size of the grating to be formed is covered with a thin film of a solution containing nano-elements, as shown in Fig.5a. In a second step the nano-
35 elements 38 of the whole film are aligned electrophoretically by means of an AC electrical aligning field, as indicated by the electrodes 40 and 42 in Fig.5b. Again, also a DC electrical or magnetic aligning field can be used.

 Subsequently the orientation of the nano-elements is frozen, for example by polymerisation if the film is a liquid polymer film. Then strips of the film are removed by

local burning, for example by illuminating the film with high- intensity radiation via a mask having a pattern of transparent slits corresponding to the intermediate strips of the grating to be formed. As a result a pattern of filmstrips comprising aligned nano-elements remains, as shown in Fig.5c, which strips form the grating strips.

5 A third method of manufacturing the diffraction grating is illustrated in Figs 6a-6. This method uses a self-assembled monolayer (SAM) 60, which is coated on a substrate 2, as shown in Fig.6a. The materials of the SAM and of the substrate are chosen such that the SAM wets the substrate. For example the SAM is hydrophobic and the substrate is hydrophilic. The SAM is strip wise exposed to actinic radiation, i.e. radiation that attacks the SAM material. The actinic radiation may be a charged- particles beam, such as an electron beam, or electromagnetic UV radiation, which passes a mask, having a pattern corresponding to pattern of the grating to be produced. As a result of the exposure, the molecules or functional groups of the SAM material within the strips are destroyed or modified such that the material no longer wets the substrate and can be removed. Thus a pattern of SAM strips 10 62, which alternate with SAM-less strips 64 is obtained, as shown in Fig.6b. This pattern is covered with a liquid containing nano-elements 38, for example by means of spin coating. The liquid is chosen such that it wets only a hydrophilic surface, thus only the SAM-less strips 64 of the substrate surface. The liquid on the SAM strips is removed as well as the SAM strips. The nano-elements in the liquid strips are aligned by means an aligning field, for 15 example an AC electrical field and subsequently the orientation of the nano-elements is frozen. As a result, a structure of strips 66 comprising aligned nano-elements, which strips alternate with empty strips 68 is obtained, whereby the strips constitute absorbing grating strips.

25 A fourth method of manufacturing the diffraction element is based on catalytic growing nano-elements on a substrate surface. First a layer, which comprises nano-element material, is deposited on the surface. Then strip shaped areas of the layer are burned out whereby a pattern of strips comprising aligned nano-elements is obtained, which strips form the diffraction strips.

30 Burning out of strips may be performed in the same way as described for the second method. The layer may be a thin metal layer, which may be deposited on the substrate by means of chemical vapour deposition (CVD) or vapour liquid solidification (VLS). Upon heating, this layer is broken up into small spheres, which are quasi-liquid. The lower sides of the spheres crystallise on the substrate and adhere thereto under the influence of catalysing elements present in the layer, for example Fe particles in case of carbon nanotubes.

In general, the above-described processes for producing a layer of nano-elements are known per se, as well as other methods, which may be used. However, the above-described methods of producing a diffraction grating or a diffraction element in general are new.

5 The structure on which the grating structure is formed may be a discrete substrate and the manufactured grating is then a discrete grating. The substrate may also be an optical element of the device wherein the grating has to be included and the manufactured grating is then integrated with said element.

10 The novel grating can replace a conventional amplitude or phase grating and shows the advantages that it is easy and cheap to manufacture and shows a high contrast between the grating strips and the intermediate strips. The capabilities of the grating can be used to the optimum extent in an optical system or device wherein two radiation beams are used, which beams follow the same radiation path, whilst only one of the beams should undergo diffraction and the other not. This can be achieved by arranging the novel diffraction
15 grating in the common radiation path and using two beams having mutually perpendicular polarisation directions, one of which is parallel to the orientation of the nano-elements in the grating strips.

 An example of such an apparatus is a device for reading and recording an optical information carrier of a first type having a first information density and an optical
20 information carrier of a second type having a second information density, which device comprises a radiation source unit supplying a first radiation beam having a first wavelength for coöperating with the first type information carrier and a second radiation beam having a second wavelength for coöperating with the second type of record carrier, and an objective system for focusing the first and second beam on an information layer of the first and second
25 type record carrier, respectively.

 The pending EP patent application 02079098.6 (PHNL020985) describes an optical scanning device for scanning in a first mode of operation a first record carrier having a first, HD, information layer and for scanning in a second mode of operation a second type of record carrier having a second, LD, information layer, which device comprises a first and a
30 second diffraction grating for splitting the LD scanning beam and the HD scanning beam, respectively into a main beam and two satellite beams.

 HD stands for high density and a high-density record carrier is for example a record carrier of the DVD (digital versatile disc) format. The HD scanning beam is the beam for recording and/or reading such a record carrier. LD stands for low density and a low-

density record carrier is for example a record carrier of the CD (compact disc) format. The LD scanning beam is the beam for recording and/or reading such a record carrier. The HD beam has a smaller wavelength, for example 650 nm, than the LD beam, for example 780 nm, so that a same objective system focuses a HD beam to a smaller scanning spot than a LD beam.

Fig. 7, which is reproduced from the EP patent application 02079098.6, shows an embodiment of the said recording/reading device, which is also called combination player. The optical path of the device comprises a radiation source 61 in the form of a two-wavelength diode laser package. A two-wavelength diode laser package is a composed semiconductor module, which has two elements 62,63 emitting radiation beams 64, 66 at different wavelength. This module may comprise a single diode laser chip having two emitting elements or two diode laser chips arranged in one package. Although the distance between the emitting elements is made as small as possible, the chief rays of the beams 64, 66 do not coincide. Nevertheless in Fig.7 HD beam 64 and LD beam 66 are represented by a single radiation beam, for sake of clarity. As the device should allow recording a HD record carrier and a LD record carrier, element 62 should emit high power red (HD) radiation and element 63 should emit high power infrared (LD) radiation.

Beam 64 emitted by the two-wavelength laser is incident on a beam splitter 68, for example a plane transparent plate arranged at an angle of, for example 45° , with respect to the chief ray of the beam. Plate 68 is provided with a, for example semitransparent reflective surface 70, which reflects the beam to a collimator lens 74. This lens converts the divergent beam into a collimated beam 76. This beam passes through an objective lens system 78, which changes collimated beam 76 to a convergent beam 80 for scanning a record carrier 90. The objective lens system may consist of a single lens element, but it may also comprise two or more lens elements, such as shown in Fig.7.

The record carrier to be scanned by means of the HD beam 64 is of a first, high density, type and comprises a transparent layer 91 having a thickness of e.g. 0,6 mm and an information layer 92, onto which converging beam 80 comes to a focus, or scanning spot 82. The radiation reflected from information layer 92 returns along the optical path of beams 80 and 76, passes the beam splitter 68 and is converged by collimator lens 74 to a detector spot 84 on a radiation-sensitive detection system 86. This system converts the beam into an electrical detector signal. An information signal representing information stored in information layer 92, and control signals for positioning focus 82 in a direction normal to the

information layer 92 (focus control) and in a direction normal to the track direction (tracking control), can be derived from the detector signal.

LD beam 66 for scanning the second type of record carrier 96 propagates along the same path as HD beam 64 towards this record carrier, which comprises a substrate
5 94 having a thickness of, e.g. 1,2 mm and a low-density information layer 95.

Record carriers 90 and 96 are drawn as a single, two layer record carrier having a semi-transparent information layer 92, but they may also be separate single-layer record carriers having different thickness transparent layers.

The LD beam should be brought to a focus, or scanning spot, 88 on the
10 information layer 95. The objective system 78 is designed such as to operate in a first mode at a first set of conjugates, whereby the HD beam from the emitting element 62 is focused on information layer 92. In the second mode the objective system operates at a second set of conjugates, whereby the LD beam from the emitting element 63 is focused on information layer 95. Radiation reflected from information layer 95 returns along the path of the LD beam
15 80, 76 passes the beam splitter 68 and is converged by means of the objective lens system into a detector spot 85 on the radiation sensitive detection system 86.

Between the beam splitter 68 and detection system 86 a beam combining-element 100 may be arranged, which makes the chief ray of the HD beam and of the LD beam co-axial so that the position of spot 84 coincides with the position of spot 85. This
20 allows using the same detection system 86 for the HD beam and the LD beam employed in the different modes, respectively. The beam-combining element may be a wavelength selective grating, which diffracts one of the HD and LD beams and passes the other without diffracting it. Preferably this grating is a blazed phase grating.

If the scanning device should allow not only reading but also recording of a
25 HD record carrier, the laser package should comprise a high power red radiation emitting element 62, instead of a low power element, and a diffraction grating, called a three spots grating, 110 should be arranged between radiation source unit 61 and the beam splitter 68. This grating comprises a transparent substrate 111 and a grating structure 112. Currently such a scanning device comprises an additional detector 102, which is arranged at the rear side of
30 the beam splitter 68. This detector supplies an output signal that is proportional to the intensity of the HD beam from element 62 and is used to control the intensity of the recording beam.

Grating 112 splits the incident HD beam into a non-deflected zero order, main, sub-beam and a plus and minus first order sub-beams. For sake of clarity ,Fig.7 shows only

the main beam. The main sub-beam forms in the information layer a main scanning spot on a track to be scanned for the purpose of recording or reading this track. The first order sub-beams form in the information layer two satellite spots (not shown), which are shifted in opposite directions, skew to the track direction, with respect to the main spot. The satellite spots are imaged in additional detector spots (not shown) on the detection system 86 and separate detector elements for these spots are provided in this system. From the output signals of the separate detector elements a track error signal, i.e. a signal comprising an indication about the deviation between the centre of the main spot 82 and the centre line of the track being scanned, can be derived. The track error signal can be used in a track servo system to keep the main spot on track. Generating a track error signal and the track servo system per se are well known in the art.

If the scanning device should also allow not only reading, but also recording of a LD type record carrier, the laser package 61 should comprise a high power infrared radiation emitting element 63 and a three-spot servo track system for the LD beam. A second diffraction grating 114 should also be arranged between the laser package 61 and the beam splitter 68. This grating should diffract only the LD beam and be a transparent plate for the HD beam, like the grating 112 being a transparent plate for the LD beam and diffracts only the HD beam. The gratings 112 and 114 may be separate elements, but preferably are integrated in a dual grating element 110 having a HD three-spot grating on one side and a LD three-spot diffraction grating 114 on the other side. By integrating gratings 112 and 114 in one component, material and manufacturing costs as well as space in the scanning device can be saved. Moreover, the number of surfaces in the radiation path is reduced so that the chance that false reflections occur is reduced.

Each of the grating structures should provide a given ratio of radiation energy diffracted in the first orders and radiation energy in the zero order for the beam it should diffract and it should be "invisible" for the beam, which it should not diffract. As stated in EP patent application 02079098.6 the grating should have a duty cycle of 50%. The duty cycle is understood to mean the ratio of the width of the grating strips and the pitch, or spatial frequency, of the grating structure. In the device of EP patent application 02079098.6 the selectivity of each grating for a different one of the two beams, HD and LD is based on wavelength selectivity. The gratings are phase gratings, i.e. the grating strips are grooves in or ridges on the grating surface and the selectivity is obtained by giving the grooves of the HD grating a smaller depth than the grooves for the LD grating.

According to the invention the said selectivity is obtained by using diffraction gratings which grating strips comprise aligned nano-elements, whereby the orientation of the nano-elements in one grating is perpendicular to the orientation of the nano-elements in the other grating, and by using a linearly polarised HD beam having the polarisation direction
5 parallel to the nano-element orientation of one grating and a linearly polarised LD beam having the polarisation direction parallel to the nano-element orientation of the other grating. In this way it is achieved that each beam is diffracted by only a different one of gratings, whereby each grating shows a high contrast for the relevant beam.

A very advantageous use of the invention can be made also in the optical
10 recording technique, but for a quite different aspect, namely for reading a high information-density record carrier by means of an optical reading device, which is designed for reading a record carrier having a lower information-density. As discussed herein above, in such a reading device an objective system, currently an objective lens, comprising one or more lens element(s) focuses the read beam to a read spot on the information layer. In the record carrier
15 information is encoded in the succession of individual information areas, which alternate in the track direction with intermediate areas. The size of the read spot is larger than the width of the individual information areas. These areas therefor diffract the incident read beam, i.e. they split this beam into a non-deflected zero order sub-beam and a number of deflected higher order sub-beams. Current optical record carriers have a reflective information layer
20 and the zero order sub-beam and portions of the two first order sub-beam reflected by the information layer pass through the objective lens. This lens concentrates the radiation portions on a radiation-sensitive detection system, whereby these radiation portions interfere with each other. When scanning the information layer, the interference pattern formed on the detection system varies and this system supplies an electrical signal, which represents the
25 information being read out.

For increasing the information density in the information layer of an optical record carrier, the size of the information areas and of the intermediate areas as well as the distance between the information tracks should be decreased. For reading information areas with a decreased size, a read spot with a correspondingly decreased size should be used;
30 otherwise the information areas can not be read separately. This means that the resolution of the reading device should be increased. The cut-off frequency of a conventional read device, i.e. the conventional cut-off frequency, is $2NA/\lambda$, wherein NA is the numerical aperture of the objective lens and λ is the wavelength of the read beam. This means that an information structure having a spatial frequency up to $2NA/\lambda$ can be read out satisfactorily. For an

information structure having a higher spatial frequency this is no longer possible. Increasing NA and/or decreasing λ could increase the resolution of the read device and thus the spatial frequency of the information structure that still can be read. The fact that the depth of focus of the objective lens is proportional to $\lambda/(NA)^2$ sets a limit to increasing NA, because for large NA the depth of focus will become too small. Reading devices with sufficient small read wavelength can be realised only when diode lasers emitting such small wavelength become available.

As described in US-A 4,242,579 the resolution can be increased by arranging that the objective lens passes only portions of the zero order sub beam and of only one of the first order sub-beams of the reflected read beam to the detection system and by using a detector, which has a small dimension in the scan direction. To that end the read beam and the record carrier are tilted relative to each other, i.e. the read beam is not incident perpendicularly on the record carrier. In this way it is achieved that for higher spatial frequencies of the information areas first order and zero order radiation still pass the objective lens and interfere on the detection system to provide an information signal. The resolution can thus be enlarged to, for example, two times the conventional resolution. As the read beam has to pass the substrate of the record carrier and this substrate has a given thickness, for example 1,2 mm, to provide sufficient mechanical strength and dust protection, an amount of aberration, such as coma and astigmatism, is introduced in the read beam. This will result in a read spot in the information layer, which is larger than required and causes cross talk.

To meet this problem, it has recently been proposed, in pending European patent application EP 03100817.0 to use a conventional optical reading device and to provide the information layer of the record carrier with a diffraction grating for directing radiation of the read beam, which is perpendicularly incident on the information layer, in a direction at a sharp angle with the chief ray of the incident beam. Providing the record carrier with such a diffraction grating allows reading with super resolution, whilst using a read beam, which is perpendicularly incident on the record carrier and passes perpendicular through the carrier substrate so that no coma and astigmatic aberration occurs. Perpendicularly incident is understood to mean that the chief ray of the incident read beam, which is currently a converged beam, is perpendicular to the record carrier. The diffraction grating is called a regular, or information-less, grating to distinguish it from the diffractive information structure.

As described in EP patent application 03100817.0 the regular diffraction grating deflects portions of the first order beams formed by the diffractive information structure such that these portions pass through the objective lens and are, together with radiation that is double refracted in the zero order, focused on the radiation-sensitive detector to interfere at the location of this detector. This detector may be the same as used in the read device disclosed in US-A 4,242,579. For further details about the effect of the regular grating in the information layer and for embodiments of the record carrier provided with such a grating reference is made to the EP patent application 03100817.0.

If K_g is the periodicity, or spatial frequency of the regular grating and K_i is the spatial frequency of the information or data structure in the information plane, the read beam will meet a structure showing an effective spatial frequency K_e , which is given by:

$$K_e = K_i - m.K_g$$

Wherein m is the used diffraction order of the regular grating, which is usually a first order. K_e will remain smaller than the conventional cut-off frequency if the grating period of the regular grating is sufficient larger. This period determines the angle at which a sub-beam of a given diffraction order is deflected by the grating: the smaller the period, the larger the diffraction angle is.

In this way an information structure having a largest spatial frequency up to, for example twice the conventional cut-off frequency can be read. This is illustrated in by means of the graphs 120 and 122 in Fig.8. In this Fig. different values for $K_i.\lambda/NA$ are plotted along the horizontal axis whilst the value for the modulation transfer function (MTF) are plotted along the vertical axis. The MTF, which maximum value is 1, is a measure for the amplitude of the information signal read from the information structure. Graph 120 represents the conventional, symmetrical situation, i.e. the whole zero order sub-beam and portions of the two first order sub-beams reflected by the information layer pass the objective lens and are used for information detection. The maximum spatial frequency K_i of the information structure that can be read is given by $K_i.\lambda/NA = 2$, thus $K_i = 2.NA/\lambda$. For this K_i value the amplitude of the read signal has decreased to nearly zero, which means that an information areas with such a spatial frequency can not be read out. Graph 122 represents the situation that the information layer is provided with a diffraction grating having the proper grating frequency. This grating effects that asymmetric portions of the zero order sub-beam and of the first order sub-beams pass the objective lens. Now the amplitude of the read signal becomes zero for $K_i.\lambda/NA = 4$, thus for $K_i = 4.NA/\lambda$, which is two times the conventional cut-off frequency.

Providing the information layer with the grating allows reading of an information structure having spatial frequencies in the range from $2.NA/\lambda$ to $4.NA/\lambda$ and thus shifts the band of spatial frequencies that can be read over $m.K_g$. However, the width of the frequency band is not enlarged and remains $2.NA/\lambda$.

5 According to an important aspect of the present invention the bandwidth can be increased by providing the information layer with the special diffraction grating described herein before. Thereby an optimum use is made of the polarisation-sensitivity of the diffraction grating. If the information layer is scanned by a radiation beam having two components with mutually perpendicular polarisation directions an information structure
10 having spatial frequencies from theoretically zero up to $4.NA/\lambda$ can be read. The beam component which has its polarisation direction parallel to the orientation of the nano-elements in the diffraction grating, thus the beam component that is diffracted by the grating is used for reading the high frequency information areas. The other beam component, which is not diffracted by the grating, is used in the conventional way to read the information areas
15 the low frequency information areas, i.e. the information areas having a spatial frequency up to $2.NA/\lambda$.

For reading a record carrier having an information structure, which shows a large spectrum of spatial frequencies, a device as shown in Fig. 9 can be used. This device comprises a diode laser 130 that emits a single radiation beam b, a collimator lens 132, a
20 beam splitter 134, an objective lens 136 and a detection branch 140. The read beam b should comprise two mutually perpendicularly polarised components. Such a beam can be obtained by orientating the cavity slit of the diode laser in an appropriate direction, such that the polarisation direction of the linearly polarised laser beam makes an angle of 45° with the orientation direction of the nano-elements in the grating 156 on the information layer 154 of
25 the record carrier 150, which has a substrate 152. Alternatively and as shown in Fig.9, a $\lambda/2$ -plate can be arranged between the diode laser and the beam splitter, which plate converts the linearly polarised laser beam into a circularly polarised laser beam, which is composed of the two mutually perpendicularly polarised beam components. The reflected beam components b_1 and b_2 , which have been modulated by information areas of high frequency and
30 information areas of low frequency, respectively have to be detected separately. This can be realized by including a polarization-sensitive beam splitter 142 in the detection branch, which splitter reflects beam component b_1 to detector 144 and passes beam component b_2 to detector 146. One of these detectors supplies a signal with frequencies up to the conventional cut-off

frequency and the other detector supplies a signal having frequencies from the conventional cut-off frequency up to twice this frequency.

Fig.10 shows the effect a regular grating has on the sub-beams diffracted by an information structure. This Fig. shows only those elements of Fig. 9 which are relevant for the inventive use of the new diffraction grating in a record carrier, namely the objective lens system 136 and the record carrier 150 with the information layer 154 and the diffraction grating 156. This grating splits an incident radiation beam in a zero order sub-beam, a plus first order sub-beam $b'(+1)$ and a minus first order sub-beam $b'(-1)$, which are denoted by interrupted arrow lines in Fig.10. The period of the regular grating is larger than the period of the information structure in the information layer so that the sub-beams $b'(+1)$ and $b'(-1)$ are deflected by the regular grating at an angle that is smaller than the angle at which the sub-beams $b(+1)$ and $b(-1)$ are deflected by the information structure. The sub-beams $b(+1)$ and $b(-1)$ are denoted by a single solid line in Fig.10. As the grating 156 is superimposed on the information structure 154, each of the first order sub-beams $b(0)$, $b(+1)$ and $b(-1)$ formed by the information structure will be further diffracted by the grating in double diffracted zero order and first order sub-beams. Of these double diffracted sub-beams, the sub-beams $b(+1,-1)$ and $b(-1,+1)$ will pass through the pupil of the objective lens system, as shown in Fig.10. The first and second index of these sub-beams relates to the order of the diffraction caused by the information structure and by the regular grating, respectively. Also the sub-beam $b(0,0)$, which has the same, but opposite direction as the incident read beam passes through the pupil of the objective lens system 136. In this way it is achieved that portions of the first order sub-beams, which are modulated by the information structure, interfere with a portion of the zero order sub-beam at the location of the radiation-sensitive detection system and reading with substantially enhanced resolution becomes possible.

This type of reading is used for the information areas having a high spatial frequency, up to two times the conventional frequency, and can only be performed by the component of the read beam, which component has a polarisation direction parallel to the direction of the nano-elements in the grating 156. The other beam component, which is not diffracted by the grating, can only read the information areas having a lower spatial frequency, up to the conventional cut-off frequency.

As is discussed in co-pending EP 03100817.0 for a conventional grating, the direction of the grating strips of the regular grating can be adapted to the arrangement of the information areas in the information layer. If these areas are arranged in tracks, the said direction may be parallel to the track direction, but preferably is perpendicular to the track

direction. In case the information areas arranged according to a 2D-OS (two-dimensional optical storage) structure, i.e. a structure composed of blocks each comprising a number of information areas, which are simultaneously read, for example by a matrix of a corresponding number of detectors, the direction of the grating strips is preferably diagonal to the blocks. Further details about this aspect can be found in EP 03100817, which is, with respect to the aspect, incorporated herein by reference.

The invention has been described at the hand of its applications, in the form of a diffraction grating, in the optical recording technique. This does not mean that the use of the grating according to the invention is limited to this technique. The grating according to the invention can be used in any optical system wherein two beams travelling along the same path are used, one of which has to be diffracted and the other not and, more general, in any optical system wherein a conventional diffraction grating is used.

The invention can not only be used in a diffraction grating but in any diffraction element which is composed of first areas, strip- or otherwise shaped, which alternate with second areas, which first and second areas have different optical properties. Another well-known example of such a diffraction element is a Fresnel (zone) lens. Fig 11 shows an embodiment of a Fresnel lens 160 according to the invention. This lens is composed of first annular shaped strips 162, which alternate with second annular shaped strips 164. The first strips 162 comprise aligned nano-elements 166, whilst the second strips 164 do not comprise such elements. The first strips absorb radiation that is polarised in the direction of alignment of the nano-elements and for such radiation element 160 acts as a Fresnel lens. For radiation that is polarised in a direction perpendicular to the direction of alignment element 160 is a neutral plate. For clearness sake only a few strips have been shown in Fig.11, in practice the number of strips may be much larger. The width of strips 162 and 164 may decrease from the centre to the border.

The Fresnel lens structure may be manufactured in a similar way as described herein above for the linear grating.

CLAIMS:

1. An optical diffraction element comprising a diffraction layer, which is divided in diffraction strips alternating with intermediate strips, characterized in that the diffraction strips comprise nano-element tubes, which are embedded in the diffraction layer and all have their symmetry axis aligned in one direction.

5

2. An optical diffraction element as claimed in claim 1, characterized in that the nano-elements are nanowires.

3. An optical diffraction element as claimed in claim 1, characterized in that the
10 nano elements are nanotubes.

4. An optical diffraction element as claimed in claim 3, characterized in that the nanotubes are carbon nanotubes.

15 5. An optical diffraction element as claimed in claim 4, characterized in that the nanotubes are single wall nanotubes.

6. An optical diffraction element as claimed in any one of claims 1-5, characterized in that it is a transmission element.

20

7. An optical diffraction element as claimed in any one of claims 1-5, characterized in that it is a reflective element.

8. An optical diffraction element as claimed in any one of claims 3-7,
25 characterized in that the material of the diffraction layer is essentially solid at temperatures below 30° C.

9. An optical diffraction element as claimed in any one of claims 3-8, characterized in that the material of the diffraction layer is liquefiable at temperatures below the temperature at which the nano-element tubes get destroyed.

5 10. An optical diffraction element as claimed in any one of claims 3-9, characterized in that the material of the diffraction layer is selected from the group consisting of glasses with melting or glass temperature below 800° C, acrylic thermoplastics and paraffin's.

10 11. An optical diffraction elements as claimed in any one of claims 1-10, characterized in that it is shaped and acts as a linear diffraction grating and in that the diffraction strips are straight grating strips.

12. An optical diffraction element as claimed in any one of claims 1-10,
15 characterized in that it is shaped and acts as a two-dimensional diffraction grating and in that it comprises two sets of straight diffraction strips, whereby the strips of the first set are perpendicular to the strips of the second set.

13. An optical diffraction elements as claimed in any one of claims 1-10,
20 characterized in that it is shaped and acts as a Fresnel lens and in that the diffraction strips are annular strips.

14. A method of manufacture the optical diffraction element as claimed in any one of claims 1-13, characterized by the steps of

- 25
- printing a pattern of strips comprising a solution containing nano-element tubes;
 - aligning the nano-element tubes in a required direction by means of an electrical or magnetic aligning field;
 - fixing the orientation of the nano-elements tubes in said direction by treating the solution in the presence of the aligning field.

30

15. A method as claimed in claim 14, characterized in that treating the solution comprises evaporating the solution.

16. A method as claimed in claim 14, characterized in that treating the solution comprises polymerising the solution.

17. A method of manufacturing the diffraction element as claimed in any one of claims 1-13, characterized by the steps of:

- spin-coating a surface area of a substrate with a thin film of a solution containing nano-element tubes;
- aligning the nano-element tubes in a required direction by means of an electrical or magnetic aligning field;
- fixing the orientation of the nano-element tubes in said direction by treating the solution in the presence of the aligning field, and
- burning out strip shaped areas of the film thereby obtaining a pattern of strips comprising aligned nano-element tubes, which strips form the diffraction strips.

18. A method as claimed in claim 17, characterized in that the step of burning out is performed by illuminating the solution with radiation of sufficient energy via a mask having a pattern of transparent and non-transparent strips corresponding to the element pattern such that a pattern of strips comprising aligned nano-elements tubes remains, which strips form the diffraction strips.

19. A method as claimed in claim 17, characterized in that the step of burning out is performed by scanning a sufficient intense radiation beam strip-wise across the solution, such that a pattern of strip comprising aligned nano-elements remains, which strips form the diffraction strips.

20. A method of manufacturing the diffraction element as claimed in any one of claims 1-13, characterized by the steps of:

- coating a substrate area with a layer of self-assembled material;
- strip-wise modifying the material of the layer so that a pattern of strips, which wet to the substrate surface is obtained and removing the rest of the layer material;
- spin-coating a liquid containing nano-elements over the pattern thus obtained, whereby the liquid wets only the bare substrate so that a pattern of liquid strips containing nano-elements is obtained;

- aligning the nano-elements in the liquid strips in a required direction by means of an electrical or magnetic aligning field, and
- fixing the orientation of the nano-elements in said direction by treating the liquid in the presence of the aligning field, thereby obtaining a pattern of strips containing aligned nano-elements, which form the diffraction strips.

21. A method as claimed in claim 20, characterized in that the step of modifying the material of the layer comprise scanning the layer strip wise by a beam of radiation.

22. A method as claimed in claim 20, characterized in that the step of modifying the material of the layer comprises illuminating the layer via a mask via a mask having a pattern of transparent slits corresponding to the strip pattern of the element.

23. A method of manufacturing the diffraction grating as claimed in any one of claims 1-13, characterized by catalytic growing nano-elements on a substrate surface from a layer, which has been deposited on the substrate and comprises nano-element material and burning out strip shaped area of the layer, thereby obtaining a pattern of strips comprising aligned nano-elements, which strips form the element strips.

24. An optical record carrier comprising at least one information layer wherein information is encoded information areas, which alternate with intermediate areas, characterized in that the information is covered by a diffraction grating as claimed in any one of claims 1-11.

25. A device for reading and recording an optical information carrier of a first type having a first information density and an optical information carrier of a second type having a second information density, which device comprises a radiation source unit supplying a first radiation beam having a first wavelength for cooperating with the first type information carrier and a second radiation beam having a second wavelength for cooperating with the second type of record carrier, and objective system for focusing the first and second beam on an information layer of the first and second type record carrier, respectively, characterized in that a diffraction grating as claimed in any one of claims 1-11 is arranged between the radiation source unit and the objective system in the common radiation path of the first and second radiation beam and in that one of the radiation beams has a first

polarisation direction parallel to the direction of the nano-elements in the grating, whilst the other beam has a polarisation direction perpendicular to the first polarisation direction.

ABSTRACT:

An optical diffraction element (1) comprises a diffraction layer (4), which is divided in diffraction strips (6) alternating with intermediate strips (8). The diffraction strips comprise nano-elements (10), which are aligned in one direction and absorb radiation (b), which is linearly polarised in this direction. The diffraction element may be a linear or two-dimensional grating (1) or a Fresnel lens (160). The polarisation sensitive grating can be used in optical systems wherein only radiation with a specific polarisation direction should be diffracted or in an optical record carrier to allow reading of an information structure with high spatial frequencies.

10 Figs 1a, 1b

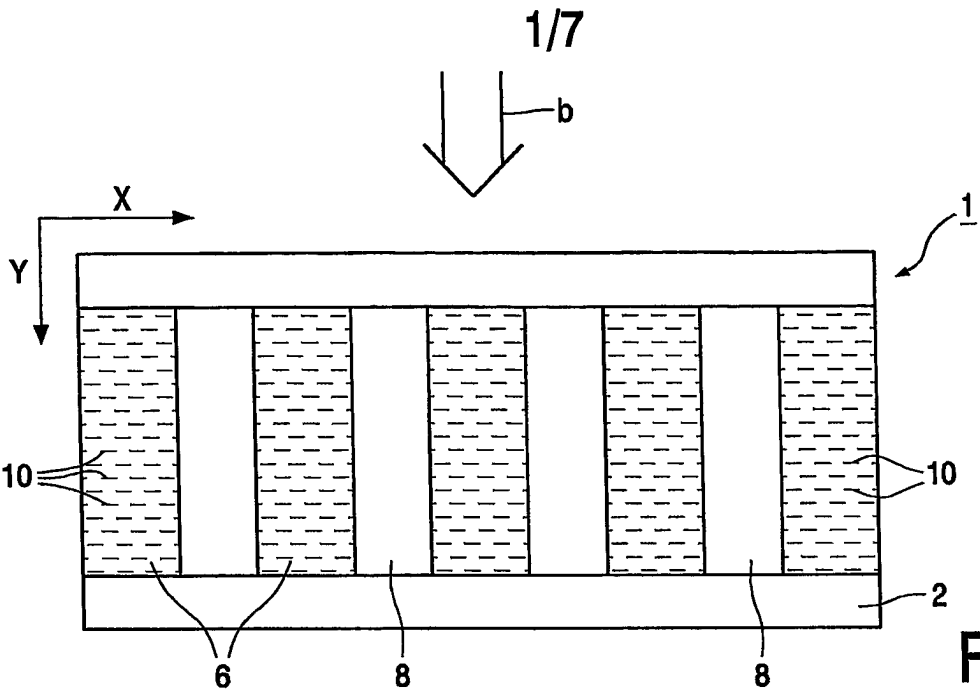


FIG. 1a

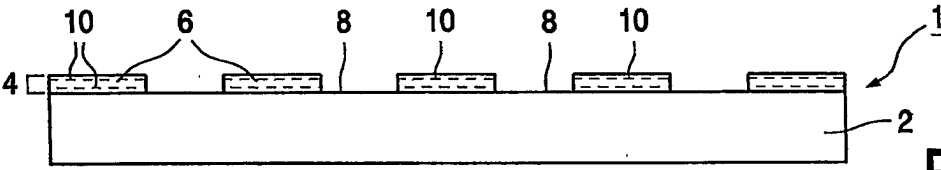


FIG. 1b

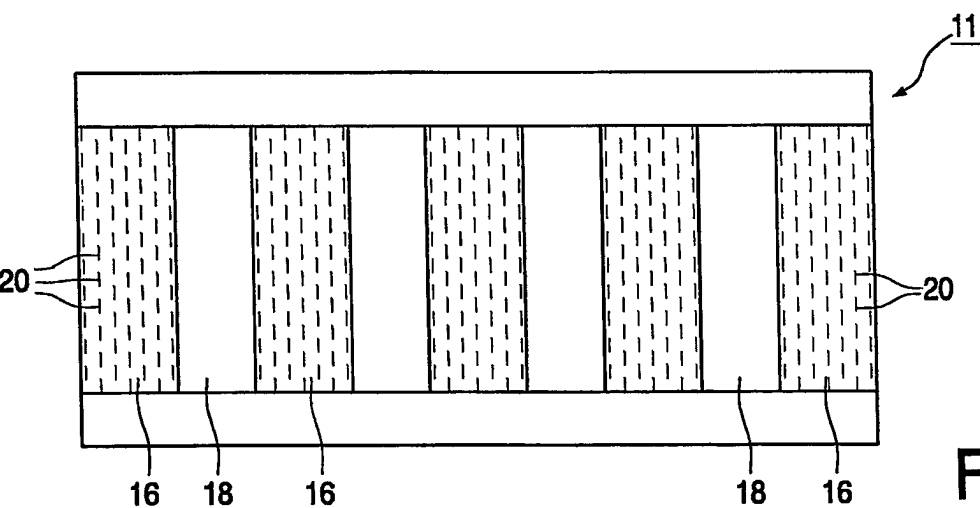


FIG. 2a

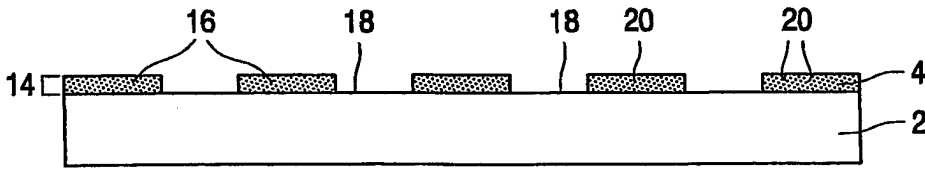


FIG. 2b

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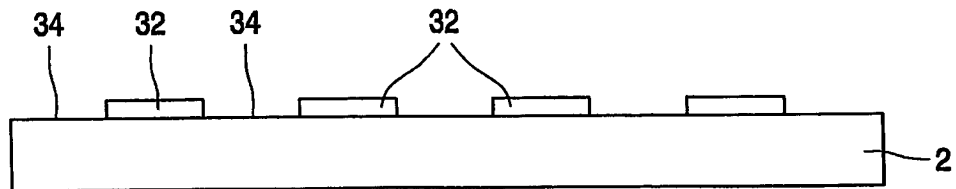


FIG. 3a

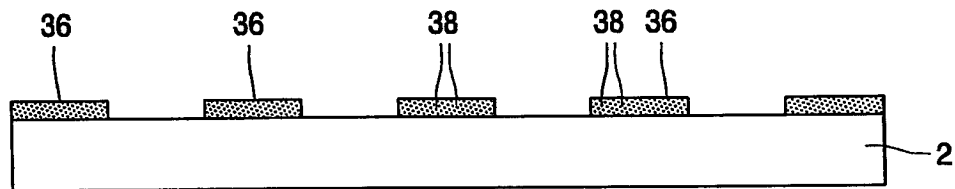


FIG. 3b

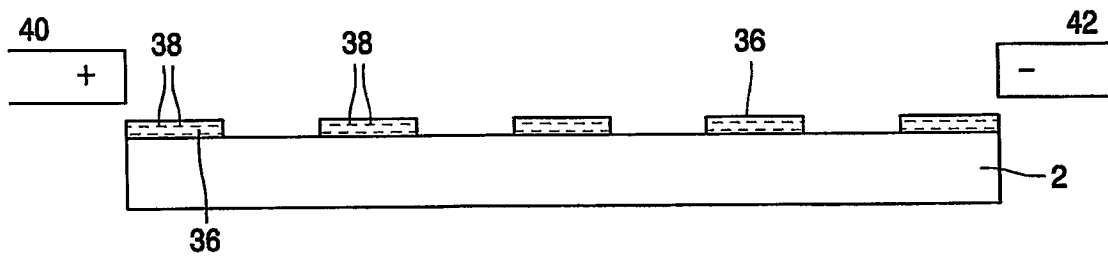


FIG. 3c

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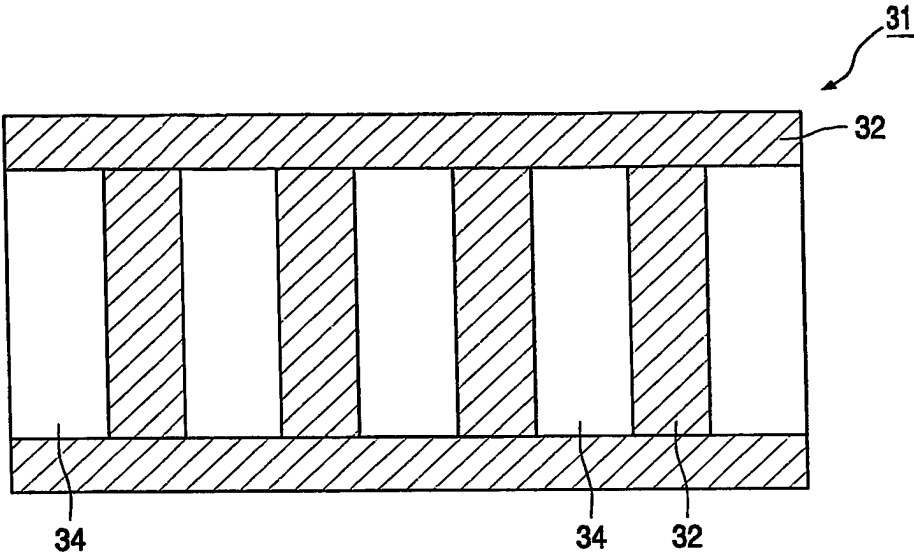


FIG. 4a

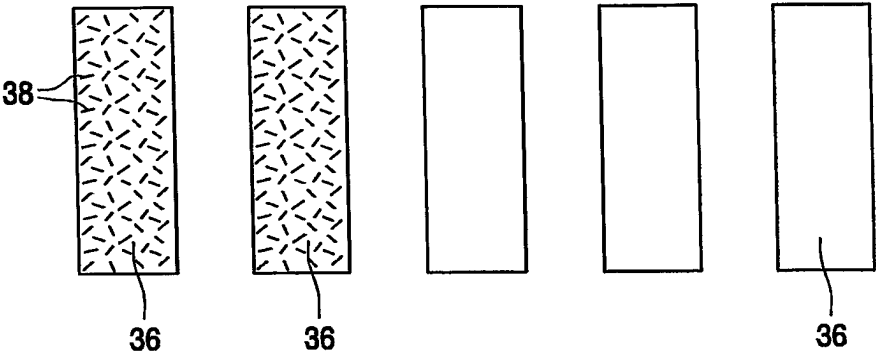


FIG. 4b

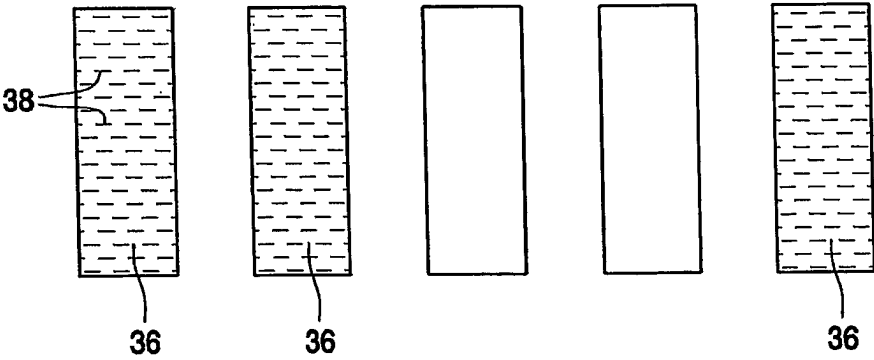


FIG. 4c

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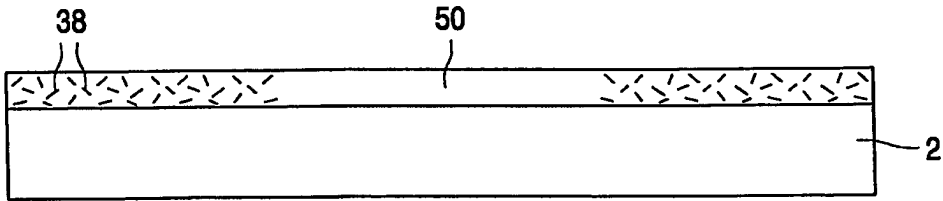


FIG. 5a

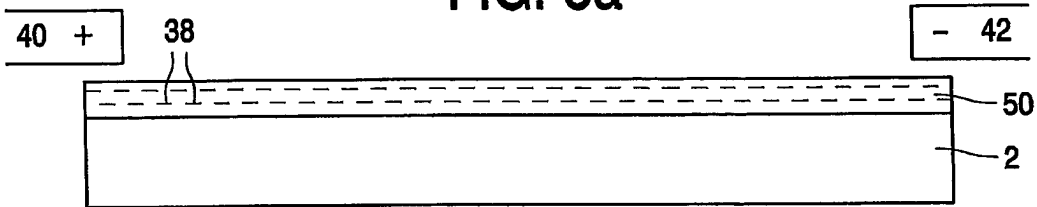


FIG. 5b

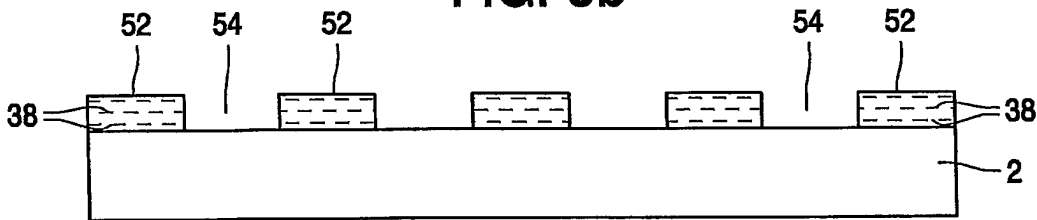


FIG. 5c

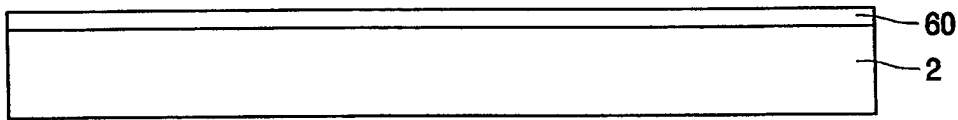


FIG. 6a

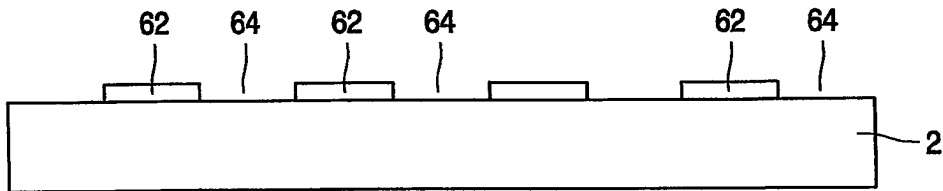


FIG. 6b

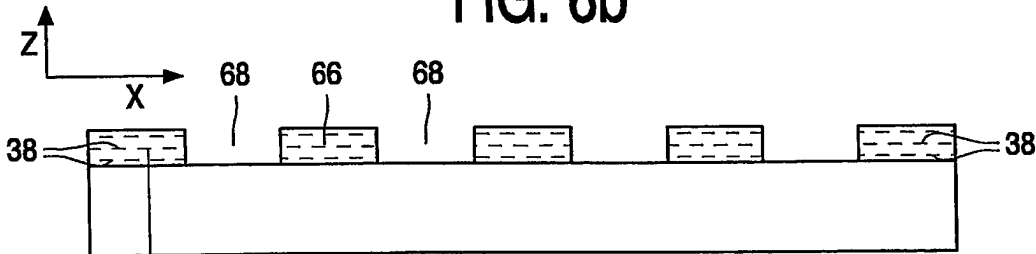


FIG. 6c

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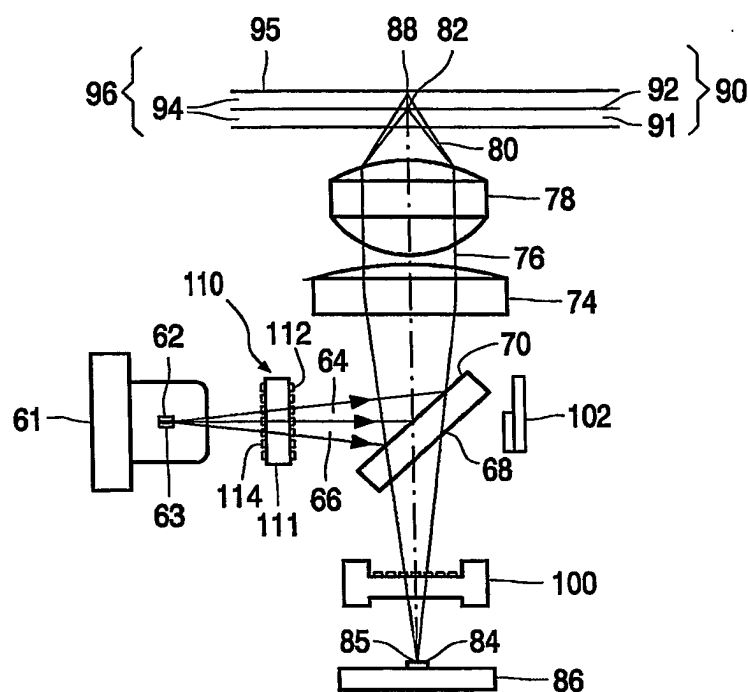


FIG. 7

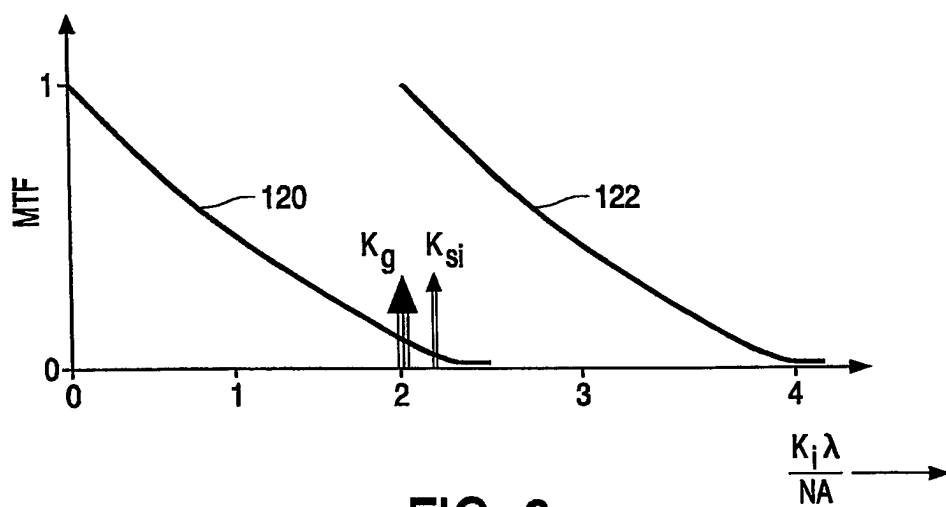


FIG. 8

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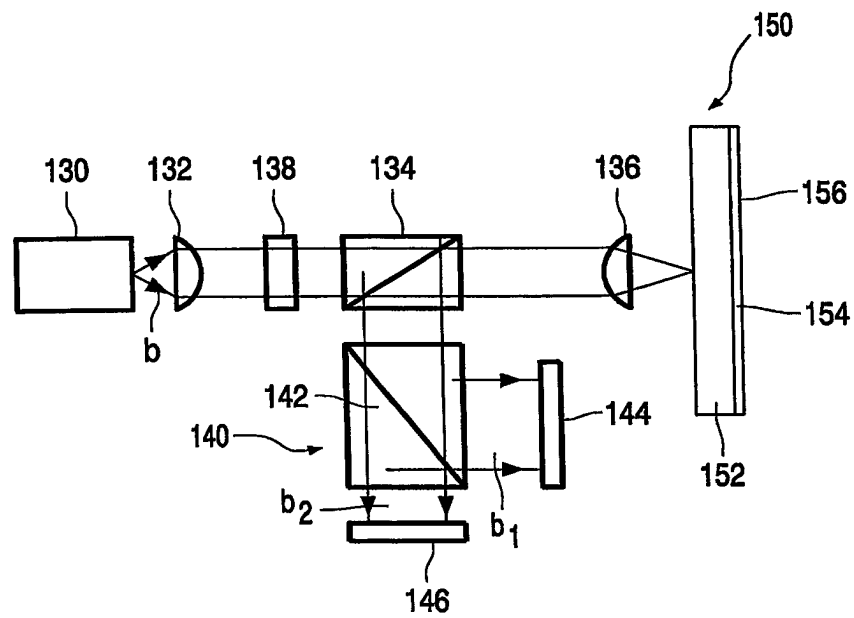


FIG. 9

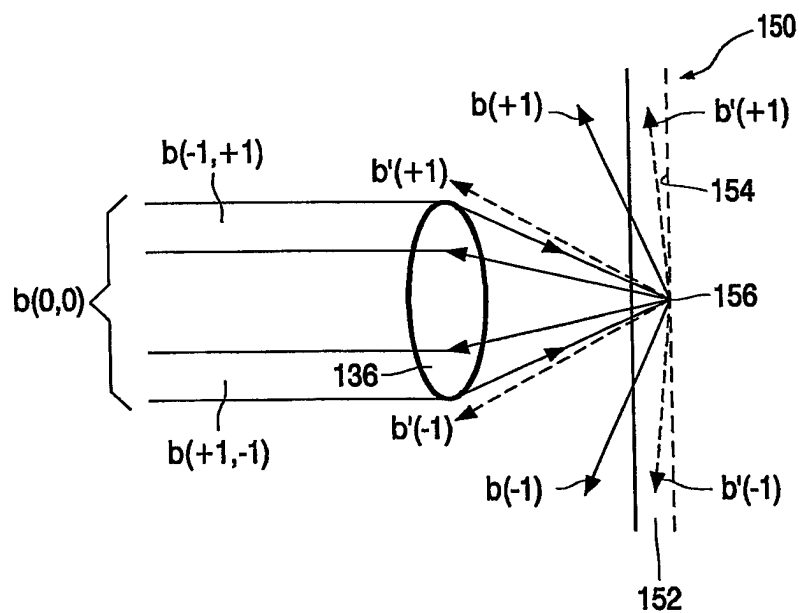


FIG. 10

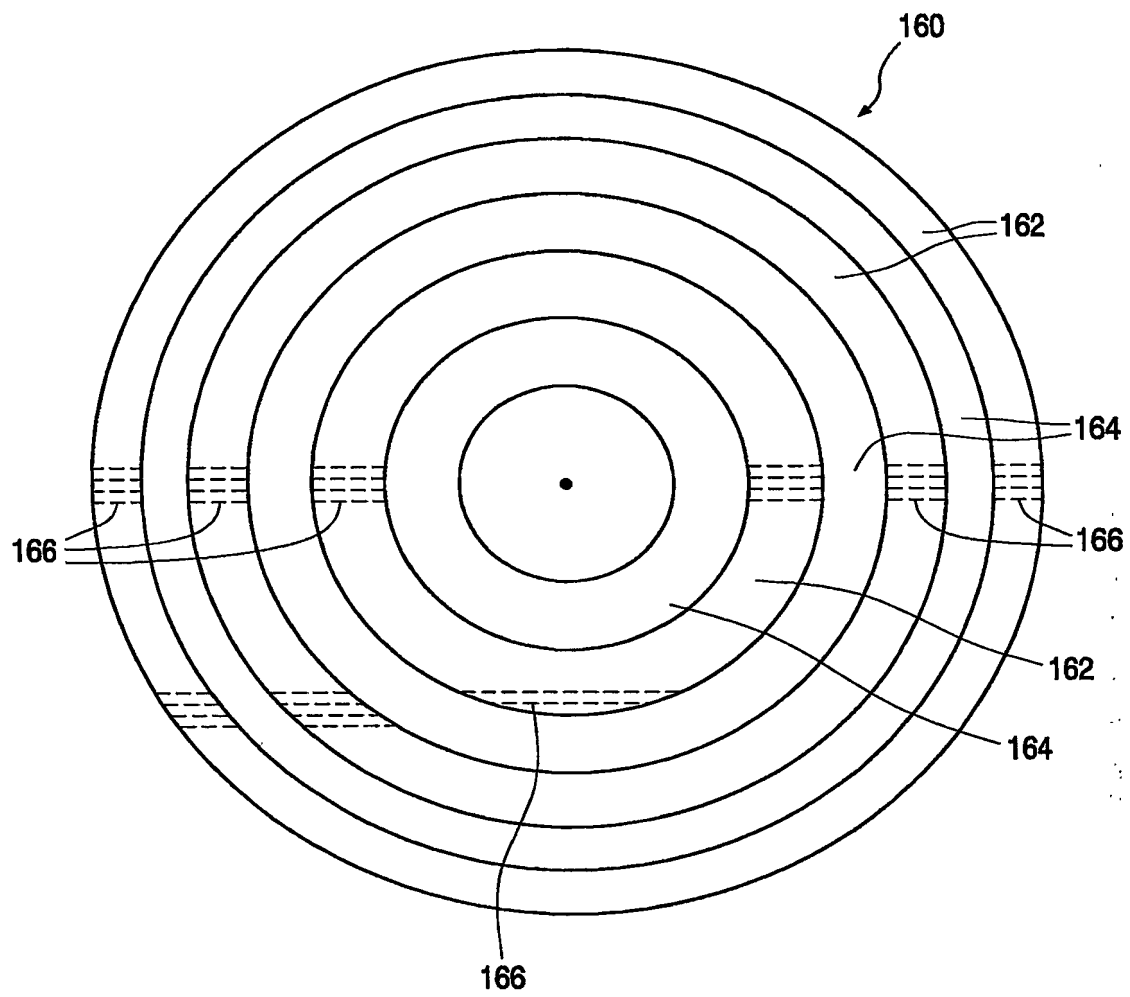


FIG. 11

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